The Nutritive Value of Feeds Produced under Conditions of Varied Soil Fertilizer Applications and Their Effects upon Growth and Reproduction in the Rabbit

A SUMMARY OF A THESIS
SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
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IN THE GRADUATE SCHOOL OF THE UNIVERSITY OF ILLINOIS, 1947

BY

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THE LACTATION RESPONSE AS LIMITED BY FEEDS PRODUCED UNDER TWO SYSTEMS OF SOIL FERTILIZATION

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ONE FIGURE

(Received for publication April 29, 1948)

Observations of certain workers indicate that varying levels of soil fertility have affected through the medium of plants the nutrition and milk production of dairy cattle (Pipers, '09; Green, '25). In other studies the weight gains of animals have been influenced (Theiler et al., '20, '24; Crampton, '34; Albrecht and Smith, '41; Webb et al., '46; Turner et al., '46). Improved palatability (Nevens, '41; Archibald et al., '43) and an increased apparent digestibility of certain forages (Nehring, '38; Eheart and Pratt, '42) have been attributed to soil fertilization; in other work the biological value of proteins in barley (Nehring and Schramm, '40) was not improved by such means. Other investigators report improved animal reproductivity, health and longevity resulting from soil fertilization (Hunt, '27; Tallarico, '31; Scheunert et al., '34).

The effects of varied levels of soil fertility upon animals have been investigated largely through the feeding of grasses or through range grazing studies. Because of the relatively meager evidence relating to such levels as they affect cereal grains and legumes, and to their ultimate influence upon the

[1] The data of this paper were taken from a thesis submitted by this author to the Graduate College of the University of Illinois in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

nutrition of animals, further study of the general problem seemed justified.

The object of this investigation was to study the lactation response in the rabbit as it is influenced by the nutrient content of feeds produced on Cisne silt loam fertilized with phosphorus and potassium and with or without calcium.

The cooperation of the Department of Agronomy of the University of Illinois made this study possible by supplying the cereal grain and legume roughages fed, which were grown on the Soil Experiment Field located at Newton, Illinois. This field was established in 1912. Since the time of its establishment accurate records have been kept of the fertilizers applied and their effects upon the productivity of the soil as shown by crop yields (Bauer et al., '45).

EXPERIMENTAL

The effects of two series of fertilizer applications upon the nutritive value of wheat grain, lespedeza hay, and soybean hay were studied through the use of paired feeding trials with lactating rabbits and their nursing young. The fertilizer series and the amounts of each fertilizer applied per acre since the field experiments were started were as follows: Series 1, raw rock phosphate, 4 tons; kainit, 2.25 tons plus 1,000 pounds of muriate of potash. Series 2 was similar to series 1 in that 4 tons of raw rock phosphate, 2.25 tons of kainit, and 1,000 pounds of muriate of potash were used, but differed from series 1 in that 12 tons of limestone were also applied. For the sake of clarity and brevity, series 1 will be referred to as the PK and series 2 as the PK + Ca treatment.

Trial 1: Lespedeza hay and wheat studies

Equal parts of ground wheat grain and ground Korean lespedeza hay (1945 crops), produced either on the PK or the PK + Ca series, and 1% sodium chloride (C.P.) were used in making up two rations. The first was known as the PK ration, the second as the PK + Ca ration. The lespedeza

produced under each soil treatment was cut on the same day, while the crop was in the early to medium bloom stage. The hay was cured under good hay-making conditions and stored with a minimum of leaf loss. Before grinding the lespedeza all of the foreign matter, chiefly weeds, was removed. The lespedeza contents of the forage as harvested from the PK and PK + Ca-treated plots were 33.3 and 71.5%, respectively.

The total nitrogen content of the lespedeza hay from the PK-treated plots was 1.96% and for the hay from the PK + Ca soil treatment, 2.36%. The two lots of wheat contained 1.53% and 1.94% nitrogen, respectively, for the PK and the PK + Ca treatments.

The percentages of dry matter, total nitrogen, and ash for the two rations as fed were (in the order named) 89.3, 1.74 and 4.6 in the PK ration and 89.9, 2.16 and 4.4 in the PK + Ca ration.

The rabbit was used as the experimental animal. Previous investigations (Crampton et al., '40; Smith and Albrecht, '42) with the rabbit have shown it to be similar to cattle or sheep in its ability to utilize feeds.

Six pairs of litter-mate New Zealand white females and two related males were used. The female of each pair was identified by a number followed by the letter "—O" if fed the PK ration, or "—W" if fed the PK + Ca ration.

Throughout the study, the paired feeding technique was used to equalize food intakes (Mitchell and Beadles, '30). After a three-week preliminary feeding period in which the experimental rations were fed, the animals were mated. Each male was mated to two females daily with only one service per female being permitted. This use of the males was not believed to be excessive (Jones and Hays, '18).

Though the females were mated at essentially the same time, because of the variability in the length of the gestation periods age in the young was calculated in days from the probable time of conception. In most instances the young were born by the end of the 31st day after conception. As soon as possible after birth the young were counted and

weighed. Usually, by the third day the litters were standardized to 6 young or less.

The feeders used were mounted high enough to prevent the young from gaining access to the rations fed. Thus the milk of their mothers was the only source of nutrients for the young.

Daily weights of litters were taken until the 46th day from the probable date of conception, at which time the litters were sacrificed. The animals of a litter were weighed individually and were measured for body length. After removal of gastrointestinal contents the carcasses were weighed, frozen and later ground for analysis.

The individual carcasses were analyzed for dry matter, total nitrogen and ash. In all, 46 carcasses were analyzed, comprising an equal number from each of the two groups compared. Because the entire litter of doe 8-O (PK) died on the 35th day after conception, the observations taken for doe 8-W (PK + Ca) and her litter have been omitted from the reported data.

Dry matter was determined by holding 1–2 gm samples of ground carcass at 100°C. for 4 hours. Total nitrogen was determined by the official Kjeldahl method (A.O.A.C., '40). Samples for ashing were placed in a muffle furnace. The temperature was slowly raised to 575–600°C. and held for 6 hours.

Trials 2 and 3: Soybean hay and wheat studies

Trials 2 and 3 differed from trial 1 in that excellent quality soybean hay was used to replace the lespedeza hay in the rations fed. The soybeans were grown under the same conditions as was the lespedeza used in the first trial.

The total nitrogen in the wheat (1946 crop) from the PK-treated soil was 1.79%, compared with 2.01% for that produced on the PK + Ca-treated plots. The soybean hay from the PK-treated soil contained 2.39% total nitrogen in contrast to 3.02% for hay from the PK + Ca-treated soil.

The ration used in trials 2 and 3 contained the same proportions of ground wheat, ground soybean hay, and sodium

chloride as were used in trial 1. The percentages of dry matter and total nitrogen in the rations as fed were 88.7 and 2.06 respectively, for ration PK, and 89.1 and 2.49 respectively for the PK + Ca ration.

TABLE 1

Weights of does and their food intakes

DOE NUMBER	DOE WEIGHTS AT TIME OF:			FEED CONSUMED DURING:	
	Mating	Parturition	Litter sacrifice	Gestation	Lactation
	kg	*kg*	*kg*	*kg*	*kg*
	Trial 1: Wheat and lespedeza hay study				
1-O [1]	3.9	3.8	3.5	3.1	2.0
1-W [2]	3.9	3.8	3.6	3.2	2.0
2-O [1]	4.0	3.9	3.7	3.7	2.2
2-W [2]	4.3	3.9	3.8	3.6	2.3
3-O [1]	4.3	4.1	3.9	3.4	1.8
3-W [2]	3.7	3.5	3.5	3.4	1.8
6-O [1]	3.9	4.0	3.7	4.1	2.6
6-W [2]	4.3	4.3	3.9	4.1	2.6
7-O [1]	3.9	3.9	3.4	3.6	2.6
7-W [2]	3.6	3.8	3.4	3.6	2.6
	Trial 2: Wheat and soybean hay study				
1O2 [2]	4.9	4.5	4.5	2.3	2.6
1W2 [1]	4.4	4.1	4.0	2.3	2.7
5-2 [2]	3.9	3.9	4.2	4.8	2.8 [3]
8W2 [1]	3.4	3.6	3.7	3.2	2.8 [3]
	Trial 3: Wheat and soybean hay study				
5-3 [2]	3.7	3.7	3.8	3.2	2.7 [3]
2W3 [1]	3.7	3.5	3.7	4.2	2.7 [3]
Average [1]	3.9	3.8	3.7	3.4	2.4
Average [2]	4.0	3.9	3.8	3.5	2.4

[1] Ration from PK-treated soil.

[2] Ration from PK + Ca-treated soil.

[3] Paired only during lactation.

Approximately 6 months after the completion of the wheat and lespedeza feeding studies the same females were again placed on experiment. In these studies the females were reversed with reference to the soil treatments as affecting the rations.

RESULTS

The PK + Ca ration that contained lespedeza appeared to be slightly more palatable than the PK ration. This was indicated by the quantity of feed that remained in the feeders

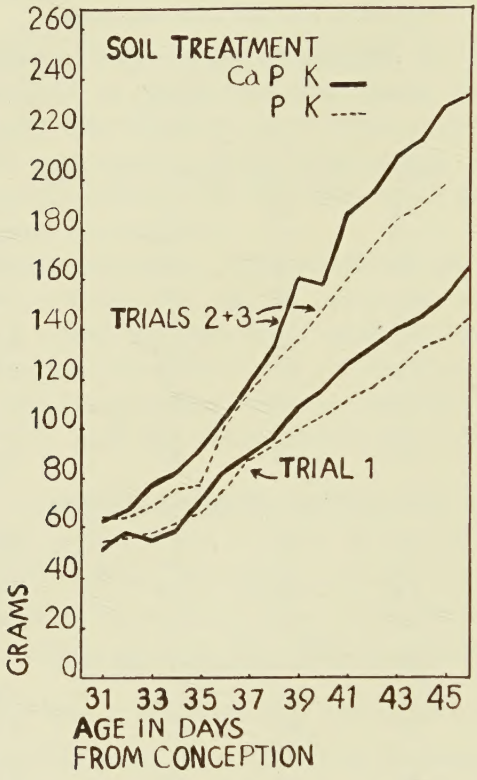

Fig. 1 The average daily weights of nursing rabbits whose mothers, in trial 1, were fed lespedeza hay and wheat and in trials 2 and 3, soybean hay and wheat. All feeds were grown on a soil that had been treated with two different combinations of fertilizers.

each day. Four of the 5 does receiving ration PK, which contained lespedeza, limited the feed intakes of their pair mates. When the soybean hay and wheat rations were fed, the tendency to limit the food intake of pair mates was about evenly divided between the two soil treatments.

A study of the average weights of the lactating females as shown in table 1 indicates that the average total weight losses while on the two rations were approximately equal. The average losses were 0.24 and 0.21 kg respectively for the PK and the PK + Ca treatments. These losses occurred from the time the females were mated until the time the young were sacrificed, 46 days later.

TABLE 2

Average body measurements and carcass composition of litters in trial 1

LITTER NUMBER	NUMBER OF YOUNG	BODY MEASUREMENTS			CARCASS COMPOSITION		
		Length	Full wt.	Empty wt.	Dry matter	Total nitrogen	Ash
		cm	*gm*	*gm*	*gm*	*gm*	*gm*
1-W [1]	6	18.6	135	124	29.0	3.3	4.2
1-O [2]	6	17.2	110	102	25.2	2.8	3.6
2-W	3	20.0	193	175	40.9	4.9	6.3
2-O	2 [3]	18.3	163	141	33.2	3.9	5.0
3-W	4	19.9	177	156	35.2	4.0	5.0
3-O	4	18.3	143	126	28.4	3.4	4.0
6-W	5	21.3	219	198	54.7	5.3	5.9
6-O	5	19.9	189	173	49.7	4.5	5.8
7-W	5 [4]	20.1	170	154	40.2	4.4	5.6
7-O	6	19.0	153	146	39.1	4.2	5.2
-W	23	19.9	176	159	39.6	4.3	5.4
-O	23	18.5	149	136	35.3	3.7	4.7

[1] "-W" = PK + Ca ration (wheat and lespedeza).

[2] "-O" = PK ration (wheat and lespedeza).

[3] One animal died 4 days before the litter was sacrificed.

[4] One animal died two days before the litter was sacrificed.

The pairs of mating totaled 17. Of the 17 females that received the PK rations, 14 bore litters averaging 6.43 young per litter, with three of the females failing to conceive. Twelve of the 17 females receiving rations PK + Ca produced an average of 7.75 young per litter, with the 5 remaining females failing to have litters. Birth weights of the individual animals in any litter were inversely related to the number of animals in the litter.

The average daily weights of the litters of nursing dams receiving the PK + Ca rations were larger than those of the litters of their paired litter mates. The differences in the average daily weights of litters were apparent after the 38th day from conception, as is shown in figure 1.

As is indicated in table 2, the average body length for the 23 young in trial 1, whose dam had been fed ration PK, was 18.5 cm as compared with an average body length of 19.9 cm

TABLE 3

Average body measurements of litters in trials 2 and 3

RATION	LITTER NUMBER	NUMBER OF ANIMALS	BODY MEASUREMENTS:		
			Length	Full wt.	Empty wt.
			cm	*gm*	*gm*
		Trial 2 [1]			
PK	1W2	3	20.8	230	209
PK + Ca	102	3	21.4	251	218
PK	8W2	4 [2]	20.2	219	186
PK + Ca	5-2	5	21.1	210	181
		Trial 3 [1]			
PK	2W3	3 [3]	19.2	205	182
PK + Ca	5-3	3	23.1	289	257
PK		10	20.0	218	191
PK + Ca		11	21.7	242	211

[1] Wheat and soybean hay studies.

[2] One animal died two days before the litter was sacrificed.

[3] One animal in this litter was quite small, weighing only 92 gm at the time of sacrifice.

for those whose dams had been fed ration PK + Ca. Although a smaller number of young survived in trials 2 and 3, their body lengths for the PK and PK + Ca rations were 20.0 and 21.7 cm respectively.

The average weight of stomach and intestinal contents of the 23 PK young in trial 1 was 12.6 gm, as compared to 16.8 gm for the 23 young reared from does on PK + Ca rations. The same trend appears in trials 2 and 3 where the gastro-

intestinal contents were 27 and 31 gm, respectively, for the PK and PK + Ca treatments.

The average quantities of dry matter, total nitrogen, and ash deposited in the carcasses, as shown in table 2, were 35.36, 3.86 and 4.79 gm respectively for those animals affected by the PK treatment. The percentages of these same components in the carcasses were: dry matter, 25.52; total nitrogen, 2.78; and ash, 3.51. The quantities of these deposition products were in direct contrast to those for the PK + Ca animals. In this group the deposited dry matter, total nitrogen and

TABLE 4

Analysis of the variance between the PK and PK + Ca treatments as affecting carcass measurements and composition of animals in trial 1

CARCASS FACTORS ANALYZED	F	COEFFICIENT OF VARIATION
		%
Body length	30.3 [1]	4.5
Gastrointestinal contents	12.9 [1]	26.6
Body weight (empty)	19.4 [1]	11.6
Dry matter deposited	8.0 [1]	13.6
Nitrogen deposited	26.5 [1]	19.0
Ash deposited	10.5 [1]	11.9
Dry matter (%) [2]	13.9 [1]	3.2
Nitrogen (%)	.0025	7.9
Ash (%)	2.9	6.6

[1] Significant at the 1% level of probability.

[2] Significantly greater in the young of the PK-nourished mothers.

ash averaged 39.66, 4.42 and 5.36 gm, respectively. Percentage values for these same components in the order named were 24.65, 2.75 and 3.39.

An analysis of the variance in the carcass observations in the first trial is summarized in table 4. The variance between treatments with respect to body lengths, gastrointestinal contents, empty carcass weights, quantity of dry matter, total nitrogen, and ash deposited was in every instance sufficiently greater than the error variance to be highly significant at the 1% level of probability. The variance between treatments

with respect to the percentage of total nitrogen and ash was only slightly greater than the error variance and was therefore not significant.

Although the differences between the values for average body lengths, gastrointestinal contents and empty carcass weights of the young produced in trials 2 and 3 showed the same trends as did those in trial 1, the number of degrees of freedom was not sufficiently large to establish the significance of the differences observed.

DISCUSSION

The causes of the wide differences in the nutritive values of the feeds grown under the two systems of soil treatment are not apparent from the data presented in this paper. It is possible that a simple correction of the protein disparity might suffice to equalize the two rations. On the other hand, it seems probable that the differences are more deep-seated than a mere difference in the nitrogen contents of the rations. Did the two systems of soil treatment cause differences in the physical as well as the chemical structure of the plant tissues? Did the addition of calcium to one series of plots enable the plants grown thereon to absorb more of some of the trace minerals? In order to determine the underlying causes of the differences which may be produced in animals by the two systems of soil fertilization, further careful research is needed. Such research is now in progress.

SUMMARY

Differences in the nutritive values of lespedeza hay, soybean hay, and wheat grain were carefully appraised through the lactation responses of rabbits. The use of doe litter mates and the paired feeding technique made such an evaluation possible.

Data are reported for 17 pairs of pair-fed, mated, doe rabbits whose rations were made up of feeds produced on a single soil type; and for 8 pairs of litters produced by these does, to an age of 46 days from conception. One ration was made

up of feeds grown on PK-fertilized soil; the other consisted of feeds grown on a similar soil fertilized with PK + Ca.

The PK + Ca rations were found to be superior to the PK rations in the following respects:

1. In trial 1 they appeared to be more palatable. No noticeable differences in palatability were observed in trials 2 and 3 when soybean hay replaced lespedeza hay.
2. The average litter size showed some tendency to be larger.
3. Average daily weights of the young were greater after reaching an age of 38 days from conception.
4. An analysis of the variance of the trial 1 data showed that body length, gastrointestinal contents, and the quantity of dry matter, total nitrogen, and ash deposited in the young fed solely on the milk of mothers fed the PK + Ca ration were significantly greater than in their PK-nourished pair mates.

Differences in the percentages of carcass nitrogen and ash were not significant.

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LITERATURE CITED

ALBRECHT, W. A., AND G. E. SMITH 1941 Biological assays of soil fertility. Soil Sci. Soc. Am., Proc., *6:* 252.

ARCHIBALD, J. G., E. BENNETT AND W. S. RITCHIE 1943 The composition and palatability of some common grasses. J. Agr. Res., *66:* 341.

ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS 1940 Official and tentative Methods of Analysis. Washington, D. C., 5th ed.

BAUER, F. C., A. L. LANG, C. J. BADGER, L. B. MILLER, C. H. FARNHAM, P. E. JOHNSON, L. F. MARRIETT AND M. H. NELSON 1945 Effects of soil treatment on soil productivity. Ill. Agr. Exp. Sta. Bull., *516:* 106.

CRAMPTON, E. W. 1934 Pasture studies. IV. Nutritive value of pasture herbage: quality of protein. Empire J. Exp. Agr., *2:* 337.

CRAMPTON, E. W., J. A. CAMPBELL AND E. H. LANGE 1940 Pasture studies. The relative ability of steers and rabbits to digest pasture herbage. Scientific Agr., *20:* 504.

EHEART, J. F., AND A. D. PRATT 1942 The digestibility and utilization by dairy cows of nutrients from fertilized and unfertilized bluegrass pasture. Va. Agr. Exp. Sta., Tech. Bull., *81:* 28.

GREEN, H. H. 1925 Perverted appetites. Physiol. Rev., *5:* 336.

HUNT, C. H. 1927 The influence of fertilizers on the vitamin B content of wheat. Ohio Agr. Exp. Sta. Bull., *415:* 1.

JONES, L. H., AND F. A. HAYS 1918 The influence of excessive sexual activity of male rabbits. I. On the properties of the seminal discharge. J. Exp. Zool., *25:* 463.

MITCHELL, H. H., AND J. R. BEADLES 1930 The paired-feeding method in nutrition experiments and its application to the problem of cystine deficiencies in food proteins. J. Nutrition, *2:* 225.

NEHRING, K. 1938 Der Einfluss von Reaktion und Düngung auf die Zusammensetzung und die Verdaulichkeit des Wiesengrases. Landwirtschaftliche Jahrbuch, *86:* 245.

NEHRING, K., AND W. SCHRAMM 1940 Über die biologische Wertigkeit des Eiweises verschiedener Gerstensorten bei wachsenden Schweinen und ihre Beeinflussung durch Stickstoffdüngung. Tierernahrung, *12:* 478.

NEVENS, W. B. 1941 Cow urine as a fertilizer for bluegrass pasture. J. Dairy Science, *24:* 761.

PIPERS, P. 1909 Fertilizers and milk production. Cultura, *21:* 332. (Chem. Abstr., *4:* 488.)

SCHEUNERT, A., M. SACHSSE AND R. SPECHT 1934 Über die Wirkung fortgesetzter Verfutterung von Nahrungsmitteln, die mit und ohne künstlichen Dünger gezogen sind. Biochem. Zschr., *274:* 372.

SMITH, G. E., AND W. A. ALBRECHT 1942 Feed efficiency in terms of biological assays of soil treatments. Soil Sci. Soc. Am., Proc, *7:* 322.

TALLARICO, G. 1931 The biological value of products from land fertilized with manure compared with fertilizers. Atti Accad. Naz. Lincei, *13:* 294. (Chem. Abstr., *26:* 238.)

THEILER, SIR ARNOLD, H. H. GREEN AND P. J. DU TOIT 1924 Phosphorus in the livestock industry. J. Dept. Agr., Pretoria, *8:* 460.

THEILER, SIR ARNOLD, P. R. VILJOEN, H. H. GREEN, P. J. DU TOIT AND H. MEIER 1920 The cause and prevention of Lamziekte. J. Dept. Agr., Pretoria, *1:* 221.

TURNER, W. F., N. F. WILLEY AND J. H. JONES 1946 Gains of heifers on native and improved pastures on the gulf coast prairie of Texas. Texas Agr. Exp. Sta. Rpt. 1018.

WEBB, R. J., J. M. LEWIS, W. G. KAMMLADE AND R. F. FUELLEMAN 1946 The level of soil fertility and its relation to plant and animal production. J. Animal Sci., *5:* 410 (Abstr.)

VITA

Kenton Augustus Kendall was born March 19, 1905, in Montgomery County near Raymond, Illinois, and lived with his parents on their dairy farm until 1928. His early education was acquired in a rural school in his home community. After graduation from Raymond Community High School, he attended Illinois State Normal University for one year. The next 4 years were spent in teaching in the rural schools near his home. In 1928, he resumed his university training at Normal University and completed the requirements for the bachelor's degree in education in 1931. From 1931 to 1940, he taught agriculture in the Carlock Township High School, Carlock, Illinois. He attended the University of Illinois during the summers and received the degree of Master of Science in Dairy Husbandry in 1940.

He spent one year teaching agriculture in the Roanoke Township High School, Roanoke, Illinois, before he became a member of the staff of the Department of Dairy Husbandry, University of Illinois, in 1941. He was married to Miss Lorene Gehlbach in June, 1940. They have three daughters, Sandra Claire, Sharon Kay, and Linda Anne. He is a member of Sigma Xi, Gamma Sigma Delta, Alpha Zeta, and Alpha Tau Alpha.